

# **Risk-Informed Inspection of Nuclear Power Plants**

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# Agenda

- **Regulatory and ASME Developments**
- **Pilot Studies - What are the benefits?**
- **What is the Future?**
- **Summary**



# US Nuclear Regulatory Commission Policy

The use of PRA technology should be increased in all regulatory matters to the extent supported by the state-of-the art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy



# Risk-Based versus Risk-Informed

- Risk-Based:
  - implies that final decision criteria are based solely on absolute risk values
- Risk-Informed:
  - used by the NRC
  - implies that decisions are based on risk insights along with deterministic and licensing basis information



# NRC Risk-Informed Regulations

- Regulatory Guide and Standard Review Plans
  - RG 1.174 General Guidance (7/98)
  - RG 1.175 In-service Testing (8/98)
  - RG 1.176 Graded QA (8/98)
  - RG 1.177 Tech Specs. (8/98)
  - RG 1.178 In-service Inspection (9/98)
- ASME - NRC PRA Standard Document
- Federal Law requires use of industry consensus standards

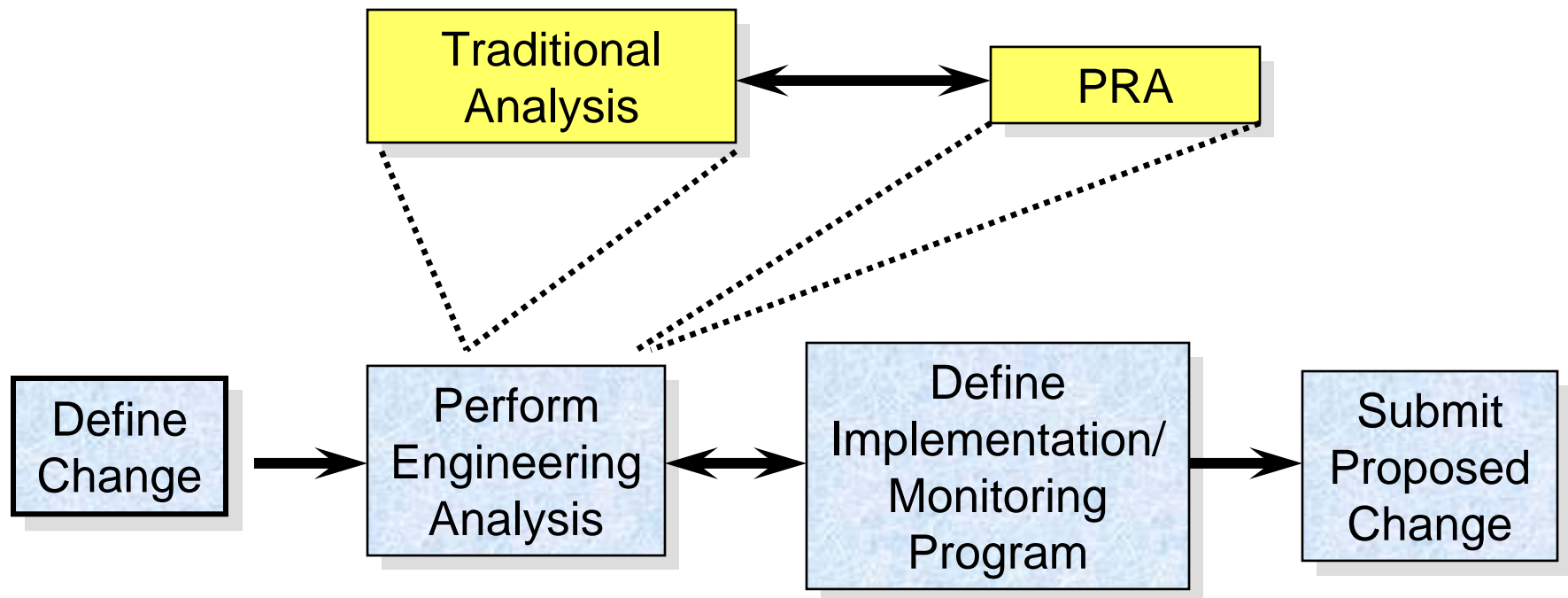


# Significance to NASA

- **In-service Testing – PRA used to select active components to test to maintain failure rate.**
- **In-service Inspection – PRA and probabilistic fracture mechanics used to select passive components (pipes, vessels) for inspection.**
- **Graded QA – PRA and deterministic criteria used to select “quality list” or risk significant components for environmental properties.**
- **Technical Specifications – PRA used to determine testing and inspection criteria and intervals.**



# NRC Regulatory Guide

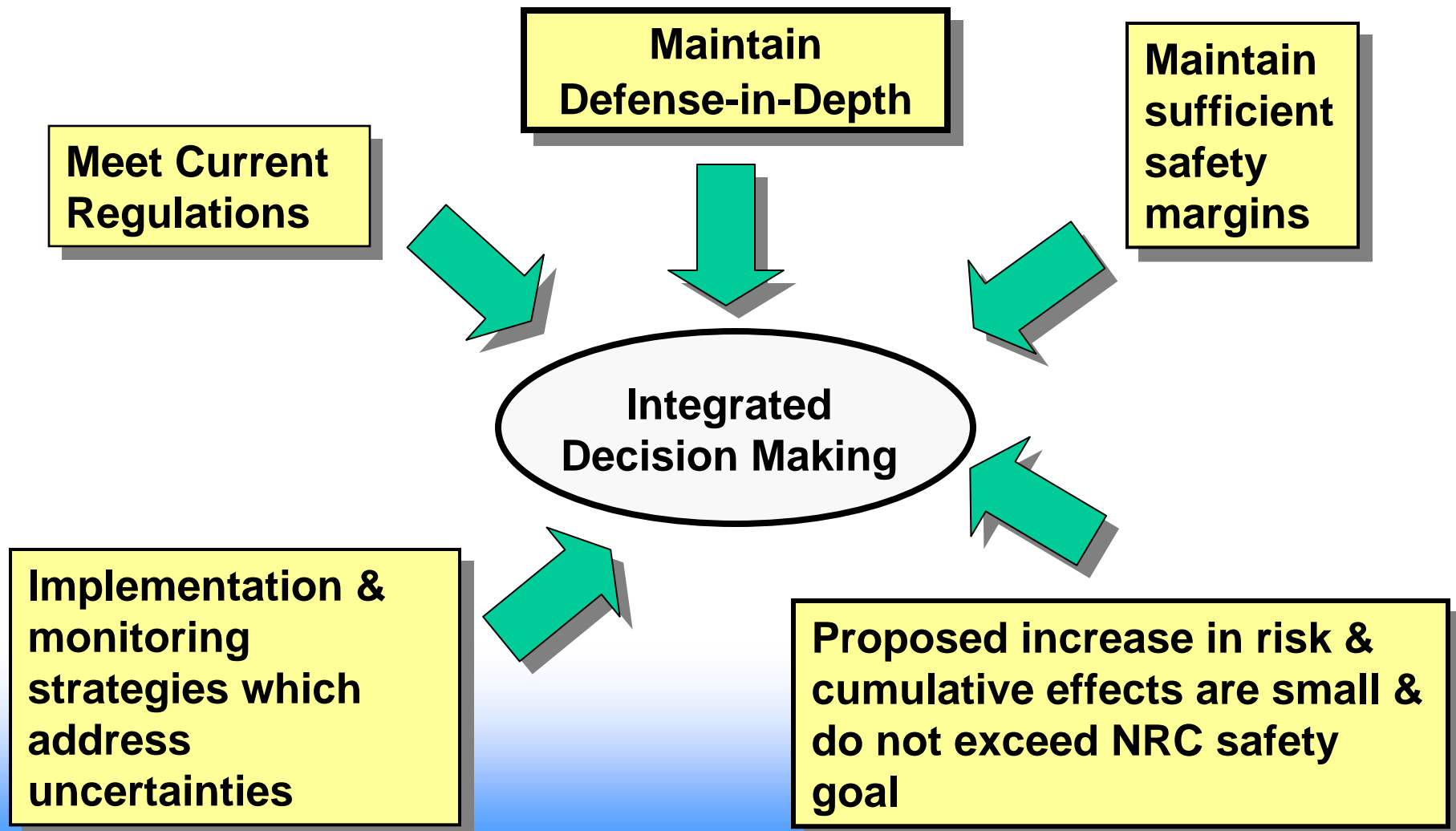


Principal Elements of Risk-informed, Plant-specific Decision Making

(from Regulatory Guide 1.176)



# Principles of Risk-Informed Regulation





# American Society of Mechanical Engineers

- Center for Research and Technology Development (CRTD)
- ASME research activities began in 1909
  - steam tables
  - the properties of gases and metals
  - the effect of temperature on strength of materials,
  - reactor vessel annealing
- Reports to Disseminate Technology
- A Leader in Risk-Based/Informed Development

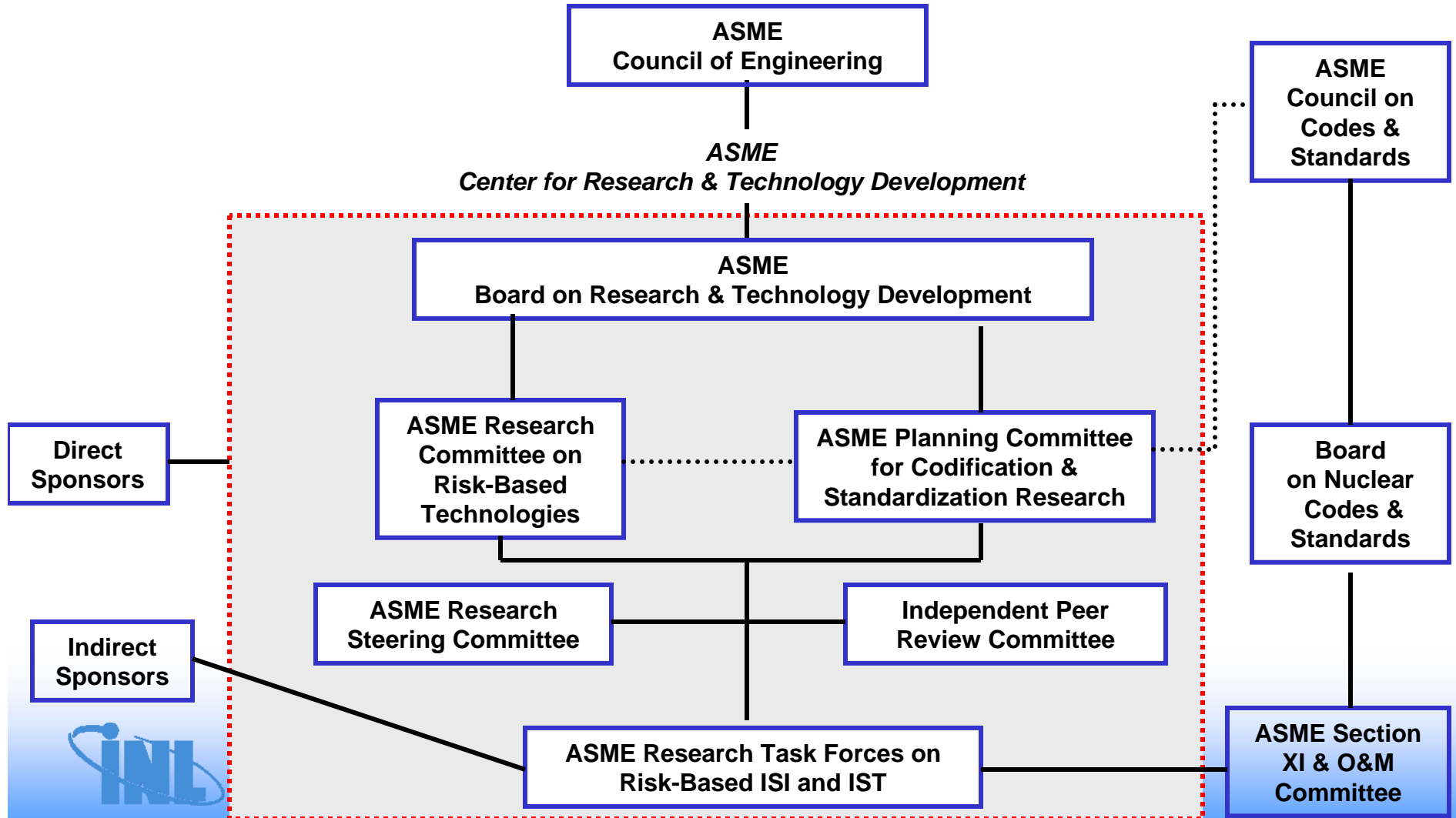


# Center for Research & Technology Development

- ASME Research Committees:
  - Risk-Based Technology: encourages risk-based technology
  - Risk-Informed Inspection
  - Risk-Informed Testing
  - Risk-Informed Design: forms the basis for the next generation of the ASME Code
  - Others as needed
- Spin Off Code Committees



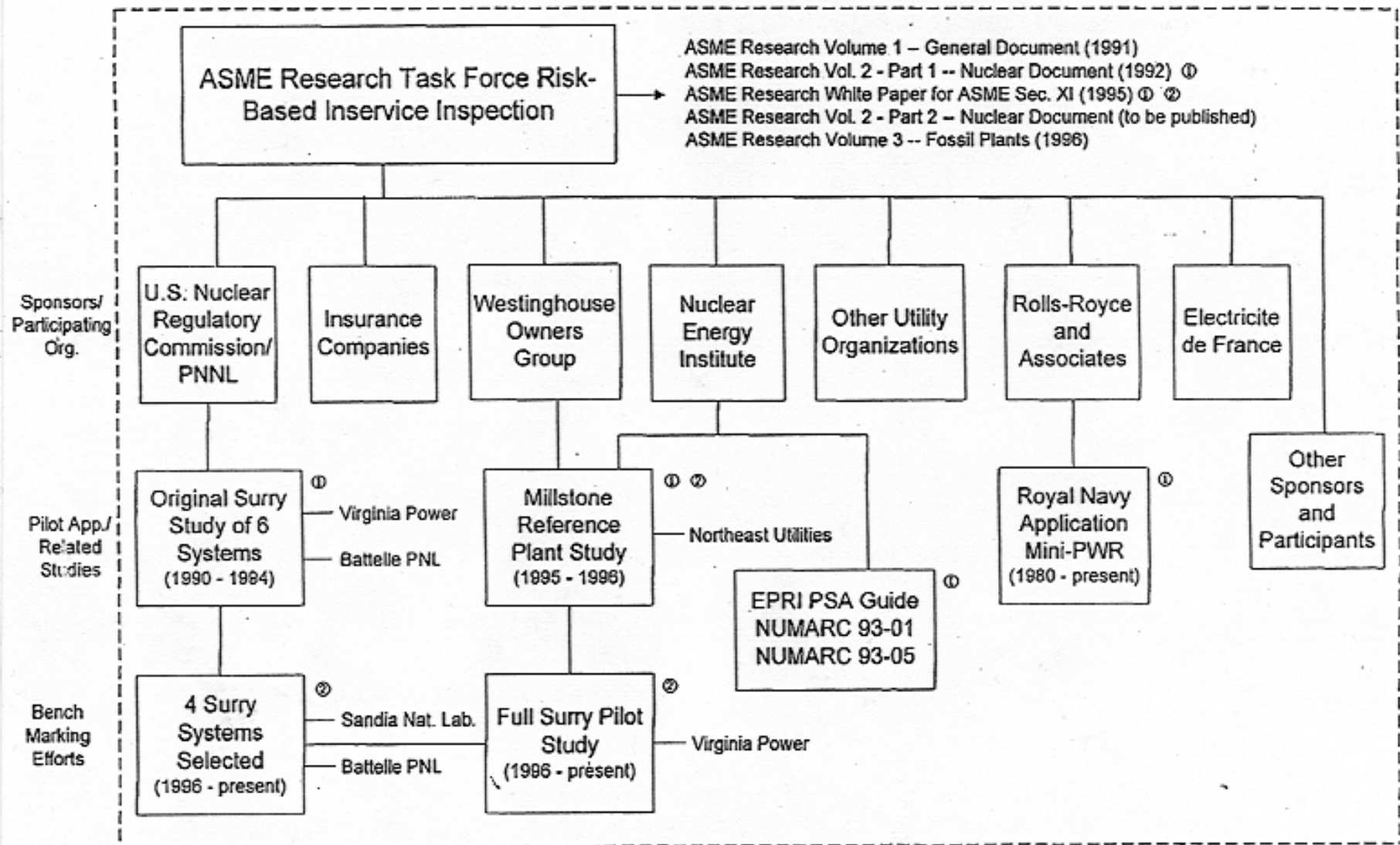
# ASME Risk-Informed ISI & IST Research Projects





# Relationship of ASME Research Efforts (for Risk-Based Inspection)

## Basis for ASME Research Methods



① ASME Research and pilot plant results used to support ASME Section XI Code Case on Risk-Based Inspection

② Pilot plant study and benchmarking efforts being used by U.S. Nuclear Regulatory Commission to develop regulatory guide and standard review plan for risk-informed inservice inspection

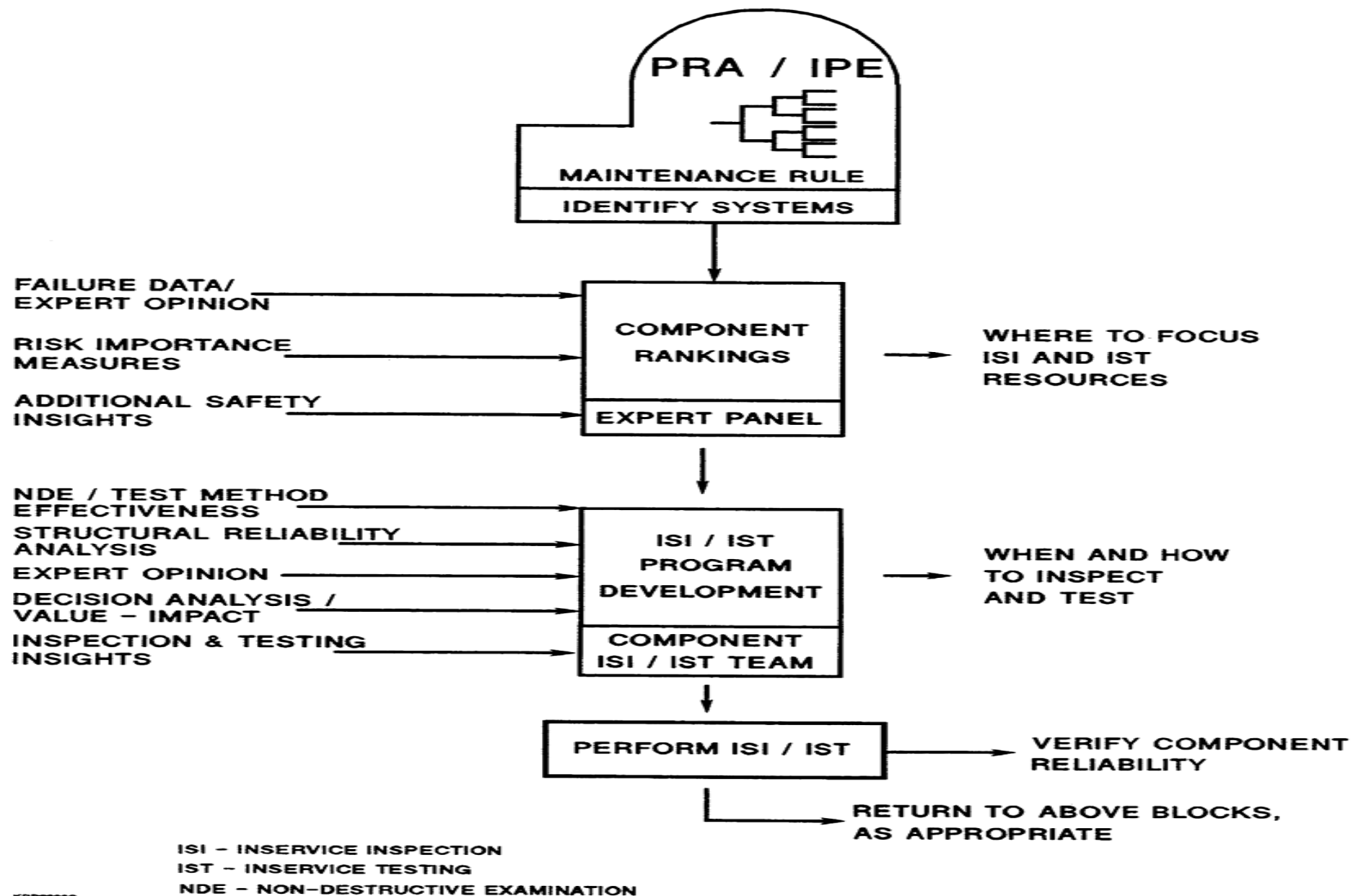


# **Risk-Informed Inspection Technique**

- **Uses PRA**
- **Uses Quantitative or Qualitative Approach**
- **Plant Engineering Knowledge - Expert Judgement**
- **Risk Importance Measures Used - Average Contribution, Risk Reduction Worth, and Risk Achievement Worth**

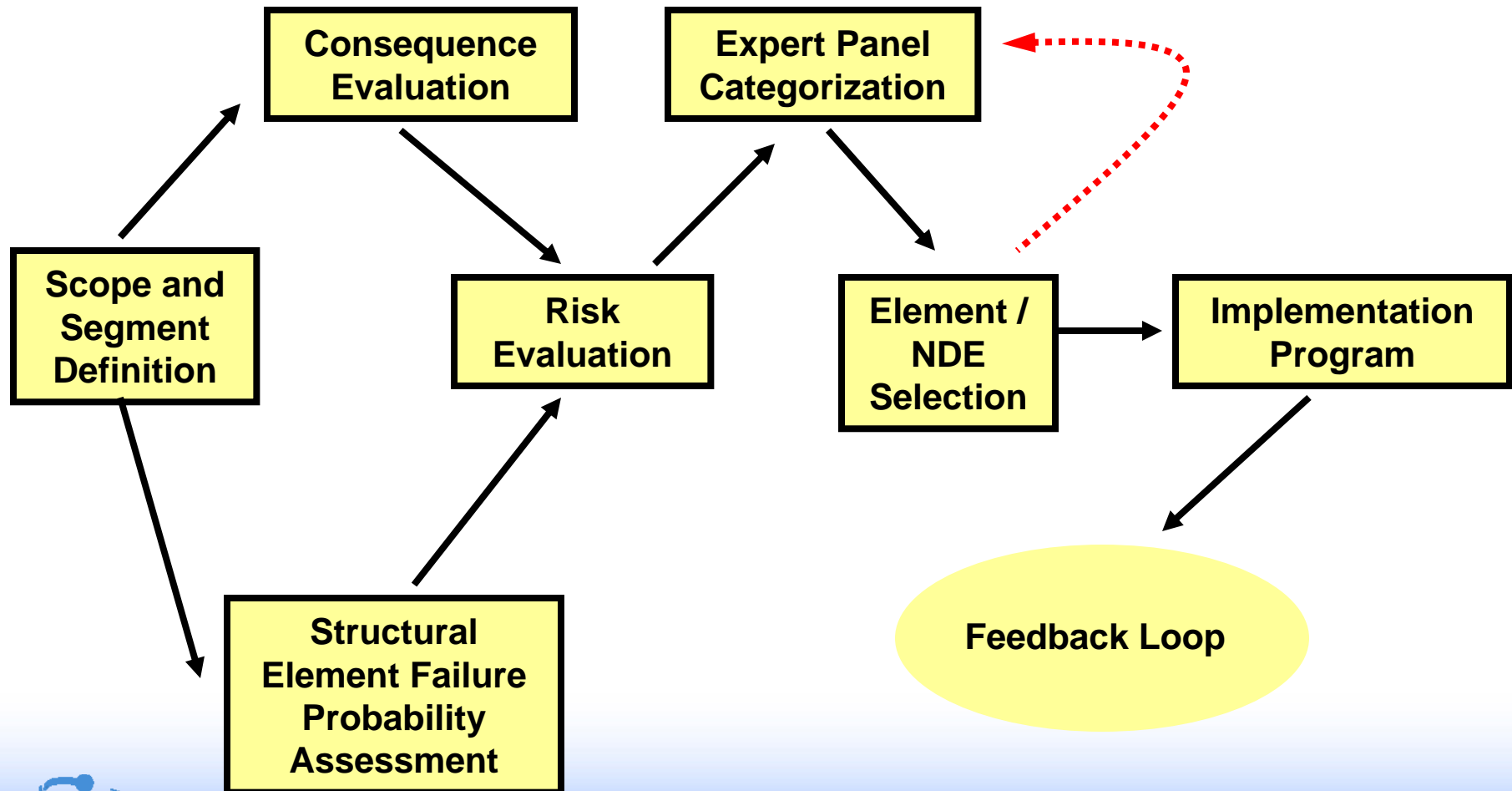


**FIGURE 1  
ASME RISK - BASED INSERVICE INSPECTION  
AND TESTING PROCESS**





# Overall Risk-Informed ISI Process





# Estimation of Piping Failure Probability

- Data - generic and plant-specific
- Probabilistic Fracture Mechanics
  - WinPRAISE, SRRA
  - Erosion/Corrosion Model by Dr. David Harris
- Pipe breaks, pipe whip, small leaks, large leaks considered to obtain primary and secondary consequences
- Expert Opinion

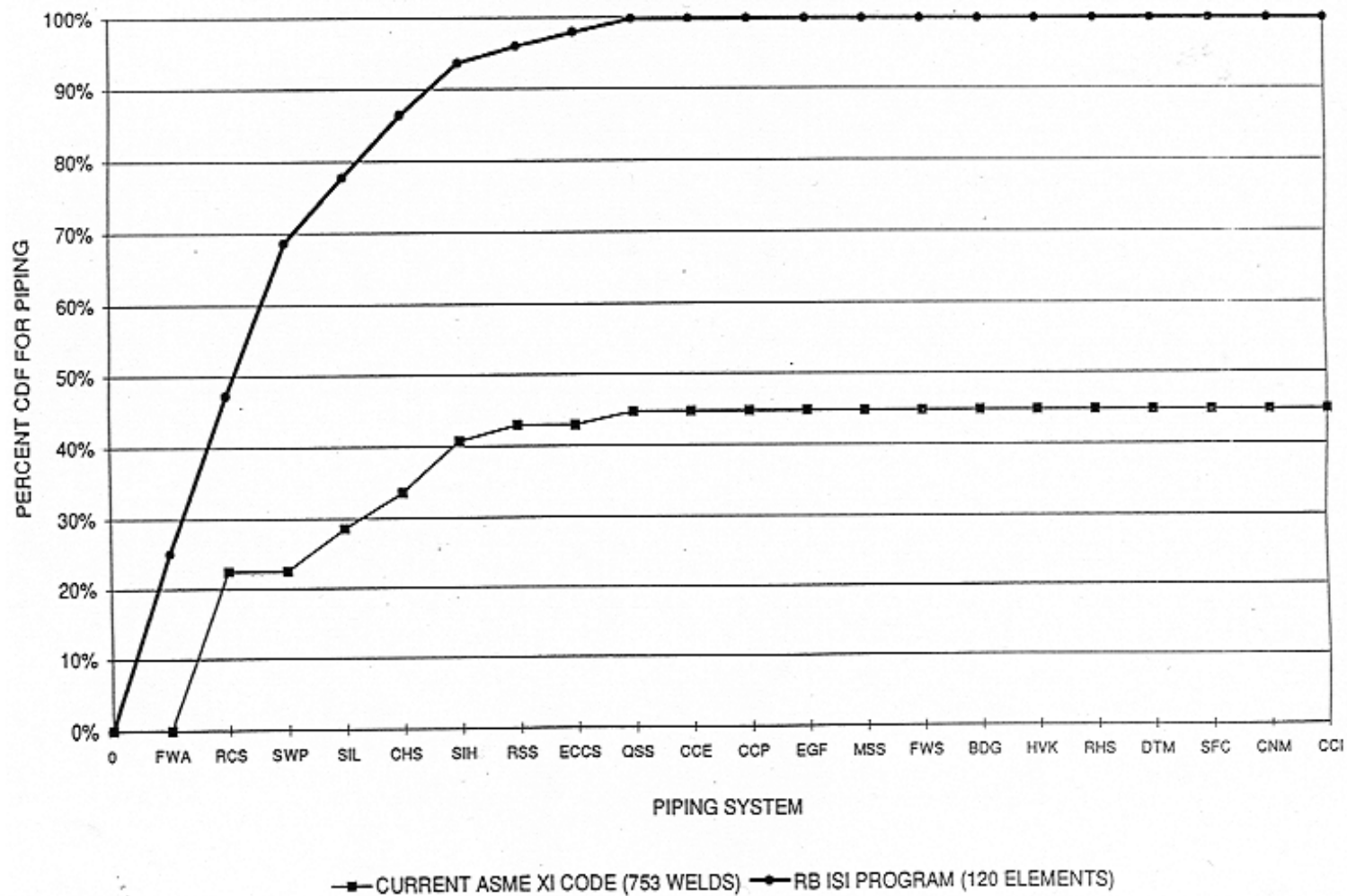


# **Risk-Informed Inspection Pilot Plant Study**

## **Millstone Nuclear Power Plant**



# MILLSTONE UNIT 3 PRELIMINARY COMPARISON OF RESULTS ON A PIPING SYSTEM LEVEL





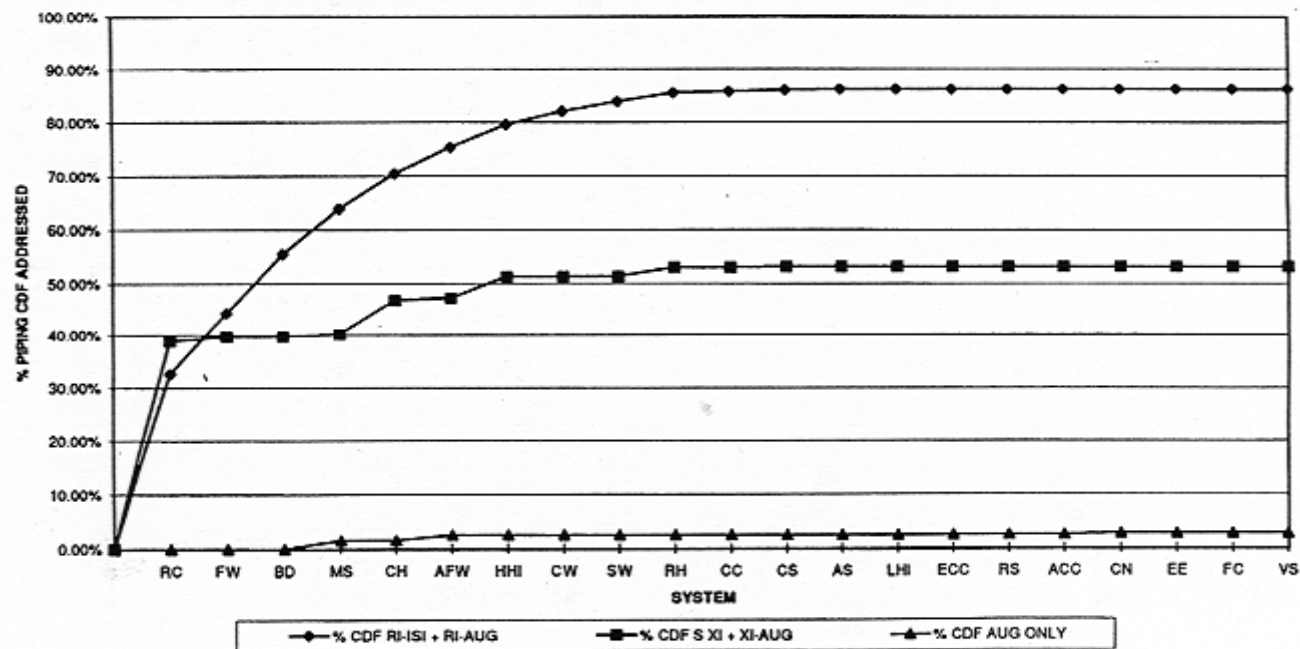
# **Risk-Informed Inspection Pilot Plant Study**

## **Surry Nuclear Power Plant**



# Surry Pilot Program

## Comparison of Risk for Surry





# Surry Pilot Plant Results Summary

- **Current ASME Section XI requires 365 NDE exams**
- **Proposed RI-ISI suggests 136 NDE exams plus 30 additional visual exams (reduction of ~65%)**
- **RCS exams reduced from 164 to 33 (80% reduction (radiation exposure reduction = 60-65 Rem each 10 year interval)**
- **Additional exams added to Class 2 & 3 and some non-Code class systems**
  - **AFW, SG, blowdown, auxiliary steam, component cooling & service water)**



# **Surry Pilot Plant Results Summary**

## **Economic Benefit Assessment**

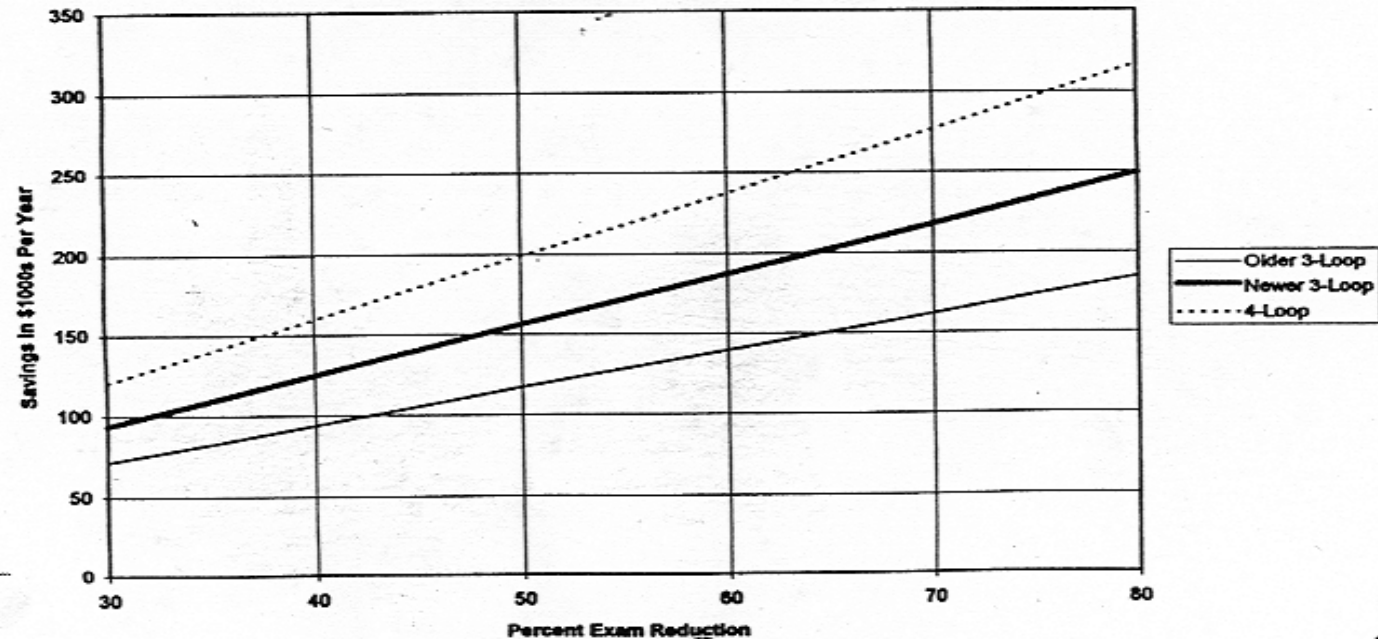
- **Virginia Power estimated \$300K for project**
- **Cost savings would be paid back in ~2 years (considering radiation exposure reduction benefit) for 3-loop plant**
- **Cost saving would be paid back in ~ 12-18 months for a 4-loop plant**



# Surry Pilot Project

## Cost Savings Estimates

Unit Type Per Annum Direct (Assuming 4K/Exam) + Exposure Cost Savings (4-Loop 15R Reduction at 80% and 3-Loop 10R Reduction at 80%, \$10000/R)



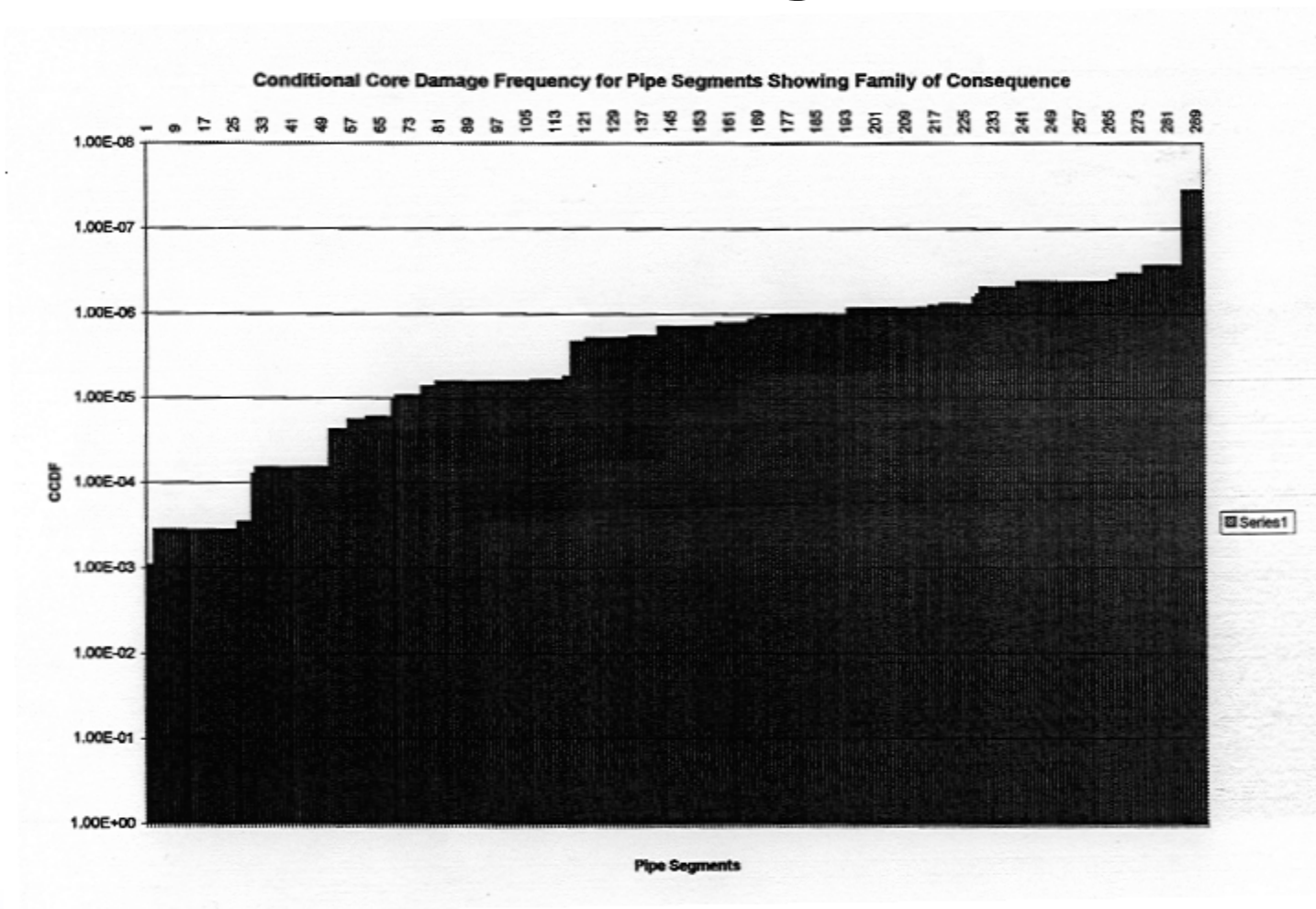


# **BWR RBI Risk-Based Inspection Program**

- **First Quantitative Boiling Water Reactor (BWR) Project**
- **Used a new version of PRAISE called WinPRAISE**
- **Extensive evaluation of IGSCC**
- **Being reviewed by the NRC**

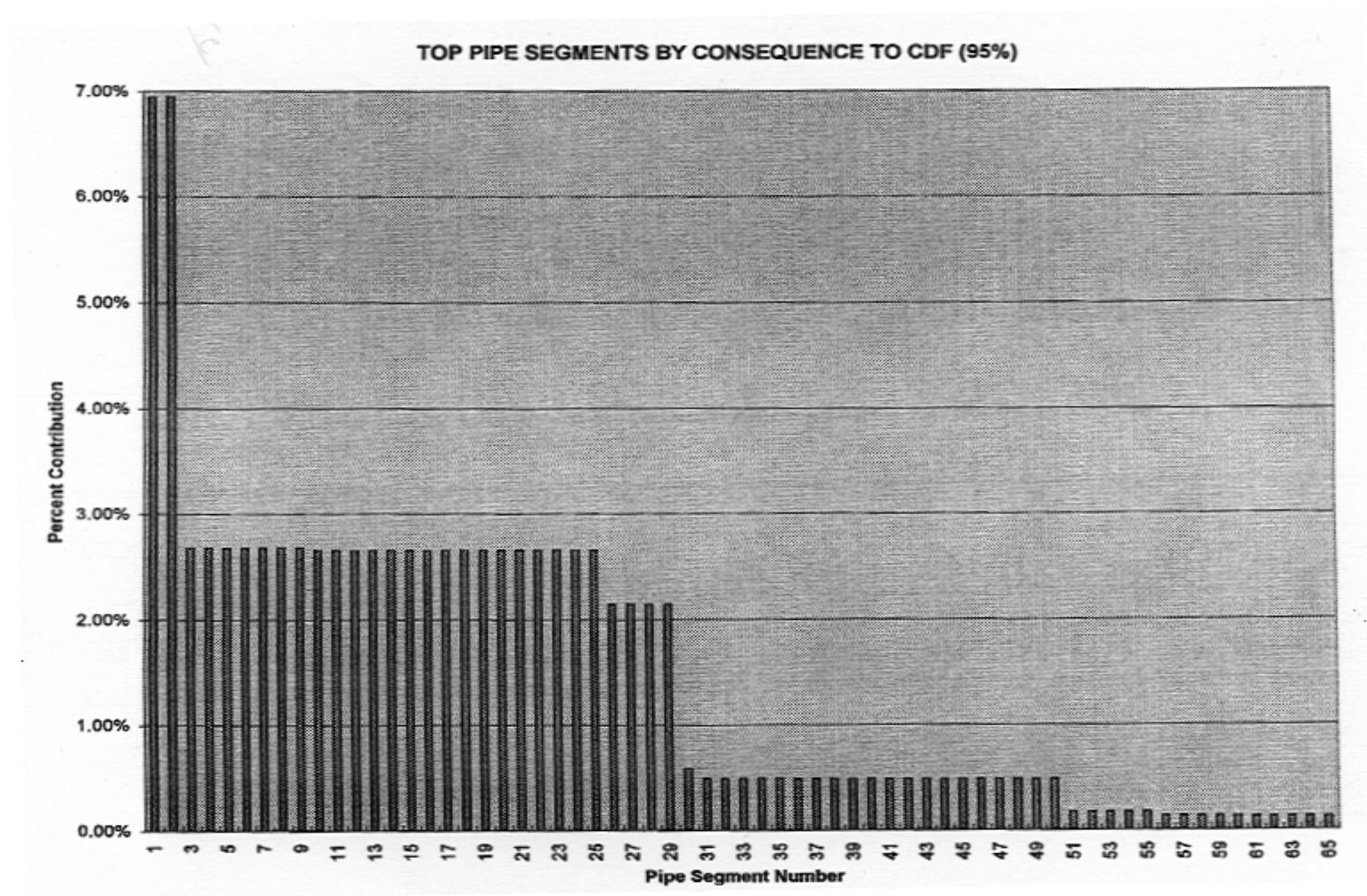


# Risk per Pipe Segment Showing Five Orders of Magnitude





# Risk Contribution per Pipe Segment



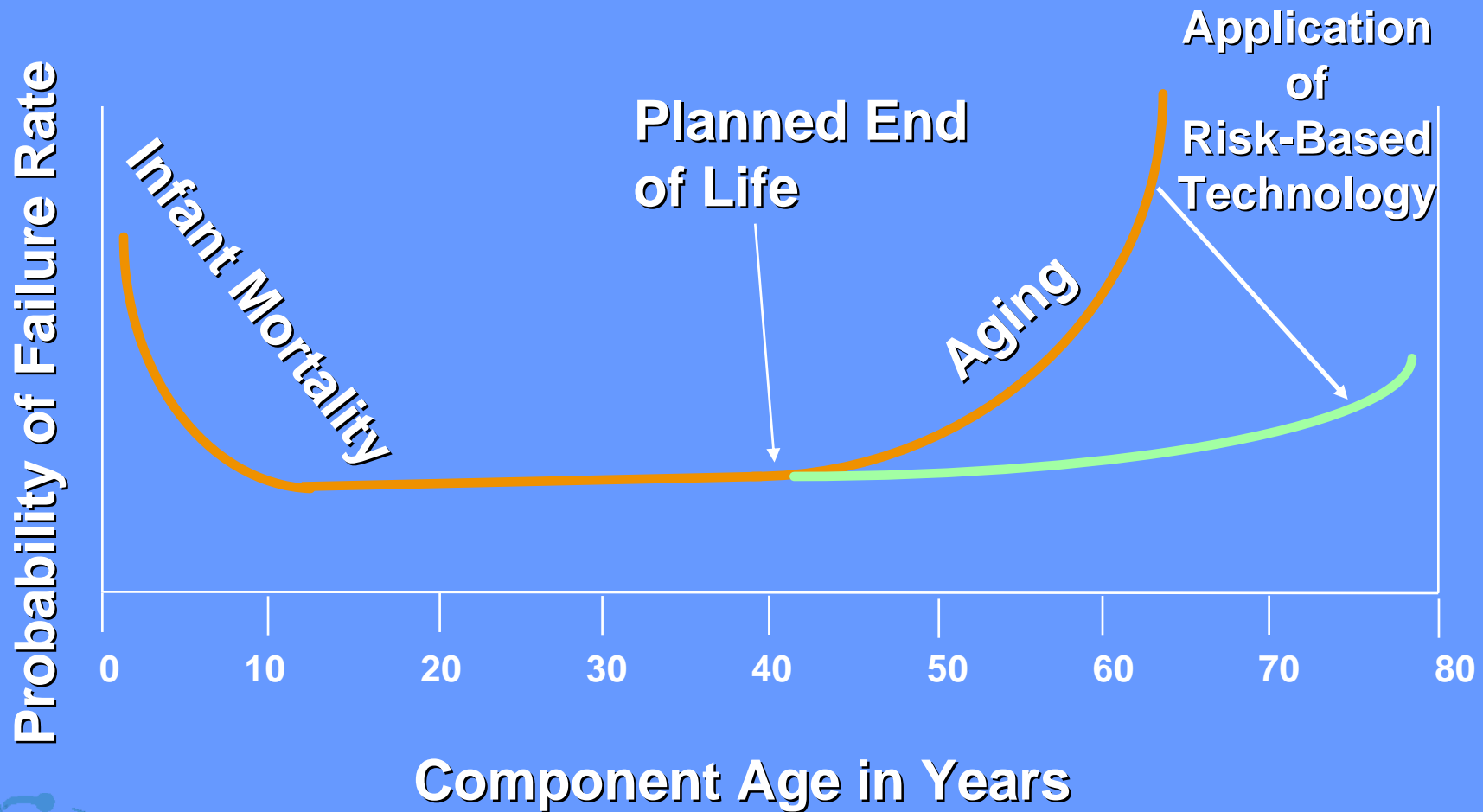


# Future Technology

- **Use Risk-Based Techniques on other industry**
- **Risk-Based Design**
- **Risk-Informed Design of High Temperature Gas Reactors**
- **Tie Risk with Economic decisions**
  - **Probabilistic Decision Analysis**
  - **Tie maintenance activity to economic decisions**
  - **ASME New Publication**



# Risk-Based Technology Applications





# Consequential Cost

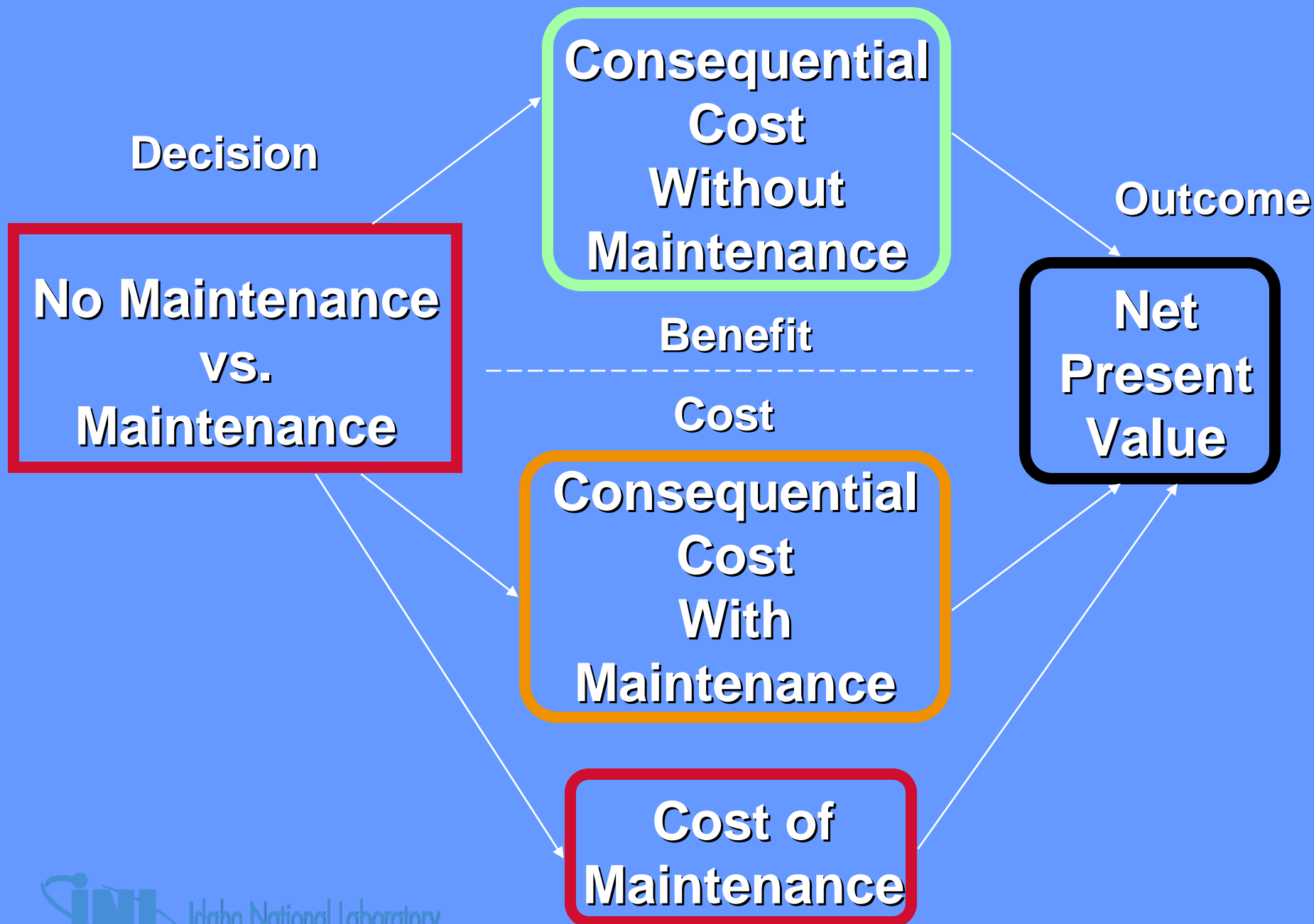
**Engineering**

**Finance**

$$\text{Risk} = \text{Probability of Failure} \times \text{Failure Consequences} = \text{Expected Failure Cost}$$

↑  
Downtime Cost  
Loss in Efficiency  
Damage Created by Failure







# Summary

- **ASME has developed techniques for over 10 years**
- **NRC has indicated direction toward risk-informed**
- **Many risk-informed project approved for use at commercial nuclear power plants**
- **Techniques increase safety and decrease costs**
- **Apply to other industry**
- **Tie risk and economics**
- **ASME handbook on risk and economics**
- **Opportunity to get involved in ASME activities**